

Supermarket Refrigeration Stakeholder Meeting #3

California Statewide Utility Codes and Standards Program

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Support from:
ICF International
on behalf of CA Air Resources Board

IOU Support for 2013 Title 24

- The California Investor Owned Utilities (IOUs) are actively supporting the California Energy Commission (CEC) in developing the state's building energy efficiency code (Title 24)
 - Base Code (Part 6 of Title 24)
 - Reach Standard (Part 11 of Title 24)
- California Air Resources Board (CARB) has supported the emissions reduction analysis conducted by ICF International
- This is the final IOU-hosted stakeholder meeting for supermarket refrigeration code change proposals, before the CEC workshop on April 18th

Schedule: Key Dates

- Mar 2010 – Feb 2011
 - CEC develop foundation /methodology
 - Investor Owned Utilities (IOUs):
 - Conduct research, and cost effectiveness analysis
 - Present results at stakeholder meetings
- Mar 2011
 - IOUs finalize code change proposals for submittal to CEC
- Apr-July 2011 Pre-Rulemaking activities
 - CEC workshops/ First Draft Language
- September 2011 – CEC rulemaking
 - CEC opens Rulemaking for Title 24, develop 45-day language
- March 1, 2012
 - Title 24 CEC Adoption date
- July 2013
 - CBSC Publication date
- Jan 1, 2014
 - Title 24 Implementation date

Meeting Protocols

- We want to hear your concerns
 - Opposing viewpoints are encouraged
 - We are seeking information, not resolution
- Time is limited
 - Ask questions/comment by “chat” or by voice
 - Clearly state your name and affiliation prior to speaking – each time
- Minutes and presentation material will be available online – we will distribute link

Telephone/Webinar Protocols

- To avoid feedback, please make sure you have a headset if you are using your computer's microphone and speakers rather than your telephone
- Please mute your microphone, unless you want to speak
- Please do not place your phone on HOLD

Submitting Comments

Informal Comment Process

- Comments can be submitted to CASE authors, substantive comments will receive responses
- Questions and responses will not be posted online, but common or frequent questions will be communicated as necessary between stakeholders
- The team will work with stakeholders to resolve issues as best we can
- The CEC has a formal comment process during later stages of the official rulemaking process

Supermarket Refrigeration Code Proposals

- Definitions
- Floating head pressure
- Condenser specific efficiency
- Floating suction pressure
- Mechanical subcooling
- Liquid-suction heat exchangers
- Display case lighting control
- Walk-in variable speed fan control
- Refrigeration heat recovery
- Secondary CO₂ cooling
- Acceptance testing

Supermarket Refrigeration

Section 101(b) Code Change Proposals

BUBBLE POINT is the refrigerant liquid saturation temperature at a specified pressure.

COOLER is space greater than or equal to 28°F but less than 55°F.

DEW POINT is the refrigerant vapor saturation temperature at a specified pressure.

SATURATED CONDENSING TEMPERATURE (CONDENSING TEMPERATURE) is the saturation temperature corresponding to the refrigerant pressure at the condenser entrance for single component and azeotropic refrigerants. For zeotropic refrigerants, the arithmetic average of the Dew Point and Bubble Point temperatures corresponding to the refrigerant pressure at the condenser entrance.

CONDENSER SPECIFIC EFFICIENCY is the Total Heat of Rejection (THR) capacity divided by the fan input electric power at 100% fan speed (including spray pump electric input power for evaporative condensers).

FREEZER is space designed to maintain less than 28°F and space designed for convertible between cooler and freezer operation.

MICRO-CHANNEL CONDENSER is an air-cooled condenser for refrigeration systems which utilizes multiple small parallel gas flow passages in a flat configuration with unitized fin surface between the gas passages, rather than round tubes arranged at a right angle to separate plate fins.

TOTAL HEAT OF REJECTION (THR) is the heat absorbed at the evaporator plus the heat picked up in the suction line plus the heat added to the refrigerant in the compressor.

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Floating Head Pressure

(a) **Condensers.** Fan-powered condensers shall conform to the following requirements.

1. All condenser fans for air-cooled condensers, evaporative-cooled condensers, air- or water-cooled fluid coolers or cooling towers shall be continuously variable speed, with the speed of all fans serving a common condenser high side controlled in unison.
2. The refrigeration system condenser controls for systems with air-cooled condensers shall use variable-setpoint control logic to reset the condensing temperature setpoint in response to ambient drybulb temperature.
3. The refrigeration system condenser controls for systems with evaporative-cooled condensers shall use variable-setpoint control logic to reset the condensing temperature setpoint in response to ambient wetbulb temperature.

EXCEPTION to Section 127 (a) 2 and 3: Condensing temperature control strategies approved by the Executive Director that have been demonstrated to provide equal energy savings

4. The minimum condensing temperature setpoint shall be less than or equal to 70°F.

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Floating Head Pressure

- Condenser control includes:
 - Floating head pressure to 70°F (or lower)
 - Variable-speed condenser fan(s)
 - Variable setpoint (ambient-following)

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Floating Head Pressure

	Energy Savings (kWh)	Energy Savings/ SF (kWh)	TDV Cost Savings (\$)	TDV Cost Savings /SF (\$)	Measure Cost plus Maintenance Cost (\$)	Benefit/ Cost Ratio
SXX Average	25,989	1.64	\$49,532	\$3.13	\$13,923	3.56
MXX Average	94,194	1.58	\$162,842	\$2.73	\$35,251	4.62
LXX Average	121,870	0.75	\$212,155	\$1.31	\$39,436	5.38
XAX Average	124,636	2.08	\$222,211	\$3.80	\$33,055	6.72
XEX Average	50,565	0.76	\$97,711	\$1.60	\$27,191	3.59
XFX Average	51,792	0.85	\$82,707	\$1.38	\$27,191	3.04

All Averages						
Arcata	91,871	1.49	\$165,461	\$2.700	\$29,537	5.60
Oakland	81,873	1.34	\$148,540	\$2.441	\$29,537	5.03
Santa Maria	84,642	1.39	\$153,901	\$2.532	\$29,537	5.21
San Diego-Lindbergh	68,631	1.16	\$130,996	\$2.208	\$29,537	4.43
Fullerton	75,743	1.27	\$150,307	\$3.129	\$29,537	5.09
Riverside	79,688	1.31	\$131,868	\$2.165	\$29,537	4.46
Sacramento	83,625	1.37	\$139,958	\$2.294	\$29,537	4.74
Fresno	80,300	1.32	\$133,652	\$2.194	\$29,537	4.52
Palmdale	90,771	1.47	\$146,744	\$2.382	\$29,537	4.97
Palm Springs	69,697	1.13	\$113,670	\$1.848	\$29,537	3.85

Maximum	204,068	2.91	\$392,707	\$9.979	\$44,484	10.37
Minimum	6,039	0.18	\$14,257	\$0.267	\$13,040	1.09

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Floating Head Pressure

- Investigated sensitivity of sensor error on evaporative condensers.
 - Concern was drift on RH sensor used for wetbulb temperature calculation.
- Analysis determined that ambient-following control is cost-effective even with significant sensor error.

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Floating Head Pressure – Charge Impacts

Energy and refrigerant charge/leak reduction economics:

	Measure Cost (\$)	Refrigerant Cost Savings Range (\$)		TDV Energy Cost Savings (\$)	Carbon Cost Savings Range (\$)		Net Savings Range (\$)	
		High	Low		High	Low	High	Low
SXX Average	\$13,923	-\$191	-\$311	\$49,532	\$4,096	\$3,269	\$39,514	\$38,567
MX Average	\$35,251	-\$963	-\$1,565	\$162,842	\$12,984	\$8,821	\$139,612	\$134,846
LXX Average	\$39,436	-\$1,135	-\$1,845	\$212,155	\$17,263	\$12,166	\$188,847	\$183,041
XAX Average	\$33,055	-\$1,908	-\$3,101	\$222,211	\$12,544	\$4,137	\$199,793	\$190,193
XEX Average	\$27,191	\$0	\$0	\$97,711	\$10,546	\$10,546	\$81,066	\$81,066
XFX Average	\$27,191	\$0	\$0	\$82,707	\$10,802	\$10,802	\$66,319	\$66,319

Arcata	\$29,537	-\$763	-\$1,240	\$165,461	\$13,781	\$10,418	\$148,942	\$145,102
Oakland	\$29,537	-\$763	-\$1,240	\$148,540	\$11,696	\$8,333	\$129,936	\$126,096
Santa Maria	\$29,537	-\$763	-\$1,240	\$153,901	\$12,274	\$8,911	\$135,874	\$132,035
San Diego-Lindbergh	\$29,537	-\$763	-\$1,240	\$130,996	\$8,934	\$5,571	\$109,630	\$105,790
Fullerton	\$29,537	-\$763	-\$1,240	\$150,307	\$10,417	\$7,055	\$130,424	\$126,584
Riverside	\$29,537	-\$763	-\$1,240	\$131,868	\$11,240	\$7,877	\$112,808	\$108,968
Sacramento	\$29,537	-\$763	-\$1,240	\$139,958	\$12,061	\$8,699	\$121,719	\$117,879
Fresno	\$29,537	-\$763	-\$1,240	\$133,652	\$11,368	\$8,005	\$114,720	\$110,880
Palmdale	\$29,537	-\$763	-\$1,240	\$146,744	\$13,552	\$10,189	\$129,996	\$126,156
Palm Springs	\$29,537	-\$763	-\$1,240	\$113,670	\$9,157	\$5,794	\$92,527	\$88,687

Maximum Net Savings	\$379,173	\$373,367
Minimum Net Savings	\$2,949	\$2,949

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Condenser Specific Efficiency

5. Fan-powered condensers shall meet the specific efficiency requirements listed in Table 127-A:

TABLE 127-A - FAN-POWERED CONDENSERS –SPECIFIC EFFICIENCY REQUIREMENTS

Condenser Type	Minimum Specific Efficiency ^a	Rating Condition
Evaporative-Cooled	160 (Btu/h)/W	100°F Saturated Condensing Temperature (SCT), 70°F Entering Wetbulb Temperature
Air-Cooled	65 (Btu/h)/W	105°F Saturated Condensing Temperature (SCT), 95°F Entering Drybulb Temperature
^a Condenser specific efficiency is the Total Heat of Rejection (THR) capacity divided by the fan input electric power at 100% fan speed (plus spray pump electric input power for evaporative condensers).		

EXCEPTION 1 to Section 127 (a) 5: Condensers with a THR capacity of less than 150 MBH at the specific efficiency rating condition.

EXCEPTION 2 to Section 127 (a) 5: Existing condensers that are reused for an expansion or remodel.

6. Air-cooled condensers shall have a fin density no greater than 10 fins per inch.

EXCEPTION to Section 127 (a) 6: Micro-channel condensers.

EXCEPTION to Section 127 (a) 6: Existing condensers that are reused for an expansion or remodel.

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Specific Efficiency – Cost Methodology

- Cost determined by increasing condenser physical size and reducing airflow and fan power – conservative approach:
 - Other options such as more efficient fan motors are probably expensive in many instances.
 - Manufacturers could make size/airflow/rerate change with minimum product re-engineering.
 - EC motors can be programmed with reduced maximum speed, making specific efficiency a factory “settable” parameter.

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Condenser Specific Efficiency

- Specific efficiency values are only slightly higher than the incentive program base case efficiencies since 2002.
 - 160 vs. 140 for evaporative condensers
 - 65 vs. 53 for air cooled condensers
- Considerations:
 - Analysis used motor nameplate whereas actual input watts that manufacturers could use may be lower, particularly on evaporative condensers
 - Catalog capacities are not certified ratings

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Condenser Specific Efficiency

	Energy Savings (kWh)	Energy Savings/ SF (kWh)	TDV Cost Savings (\$)	TDV Cost Savings /SF (\$)	Measure Cost plus Maintenance Cost (\$)	Benefit/ Cost Ratio
SXX Average	2,282	0.13	\$14,214	\$0.87	\$1,656	26.54
MXX Average	7,483	0.12	\$20,161	\$0.33	\$3,599	13.45
LXX Average	8,728	0.06	\$27,115	\$0.18	\$5,696	9.35
XAX Average	7,069	0.12	\$23,949	\$0.53	\$5,526	6.54
XEX Average	3,529	0.05	\$9,055	\$0.22	\$795	50.13
XFX Average	2,282	0.13	\$14,214	\$0.87	\$1,656	26.54

All Averages						
Arcata	1,507	0.028	\$3,353	\$0.06	\$3,571	3.72
Oakland	2,181	0.040	\$5,533	\$0.10	\$3,571	4.29
Santa Maria	2,438	0.040	\$4,569	\$0.08	\$3,571	4.01
San Diego-Lindbergh	2,937	0.054	\$6,586	\$0.12	\$3,571	4.65
Fullerton	3,268	0.058	\$10,472	\$0.18	\$3,901	5.21
Riverside	5,353	0.093	\$19,110	\$0.32	\$3,901	6.94
Sacramento	4,540	0.079	\$17,493	\$0.29	\$3,901	6.55
Fresno	6,692	0.114	\$21,812	\$0.36	\$3,901	7.47
Palmdale	6,629	0.113	\$21,694	\$0.36	\$3,901	7.15
Palm Springs	13,409	0.225	\$33,395	\$0.55	\$3,901	10.32

Maximum	26,006	0.35	\$ 66,062	\$ 0.86	\$ 9,862	24.70
Minimum	386	0.01	\$ 756	\$ 0.02	\$ 79	0.32

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Condenser Specific Efficiency

- Analysis results for situations with BCR < 1:

	Energy Savings (kWh)	Energy Savings/SF (kWh)	TDV Cost Savings (\$)	TDV Cost Savings /SF (\$)	Measure Cost (\$)	Benefit/ Cost Ratio
CTZ01 – Arcata						
SAD-Non-EC	431	0.03	\$979	\$0.06	\$1,103	0.89
LAC-Non-EC	1,897	0.01	\$4,414	\$0.03	\$5,540	0.80
LAD-Non-EC	1,334	0.01	\$2,857	\$0.02	\$5,636	0.51
CTZ03 – Oakland						
LAD-Non-EC	1,828	0.01	\$4,993	\$0.03	\$5,636	0.89
CTZ05 – Santa Maria						
LAD-Non-EC	4,759	0.03	\$3,943	\$0.02	\$5,636	0.70

- Specific efficiency is not cost-effective in
 - Arcata (CTZ01)
 - Oakland (CTZ03)
 - Santa Maria (CTZ05)
- Exception to be added based on either climate zone or design dry-bulb temperature.

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Floating Suction Pressure

(b) Compressor Systems. Refrigeration compressor systems and condensing units shall conform to the following requirements.

1. Compressors and multiple-compressor suction groups shall include control systems that use floating suction pressure logic to reset the target saturated suction temperature based on the temperature requirements of the attached refrigeration display cases or walk-ins.

EXCEPTION 1 to Section 127 (b) 1: Single compressor systems that do not have variable capacity capability.

EXCEPTION 2 to Section 127 (b) 1: Suction groups that have a design saturated suction temperature of 30°F or higher, or suction groups that comprise the high stage of a two-stage or cascade system or that primarily serve chillers for secondary cooling fluids.

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Floating Suction Pressure

- Standard practice in most stores
 - FSP logic standard in rack controllers
 - Temperature sensors in cases and walk-ins (needed for FSP) are standard
- Requires coordination with other controls
- Cost is primarily labor to program, fine-tune and maintain

Supermarket Refrigeration

Floating Suction Pressure

	Energy Savings (kWh)	Energy Savings/SF (kWh)	TDV Cost Savings (\$)	TDV Cost Savings /SF (\$)	Measure Cost plus Maintenance Cost (\$)	Benefit/Cost Ratio
SXX Average	8,428	0.53	\$16,508	\$1.04	\$5,075	3.25
MXX Average	33,799	0.57	\$65,475	\$1.10	\$10,149	6.45
LXX Average	50,213	0.31	\$98,996	\$0.61	\$10,149	9.75
XAX Average	30,047	0.46	\$60,311	\$0.93	\$8,458	7.13
XEX Average	26,407	0.39	\$50,531	\$0.75	\$8,458	5.97
XFX Average	33,782	0.51	\$65,240	\$0.99	\$8,458	7.71

All Average						
Arcata	28,549	0.44	\$54,689	\$0.841	\$8,458	6.47
Oakland	29,510	0.45	\$57,071	\$0.874	\$8,458	6.75
Santa Maria	29,299	0.45	\$56,655	\$0.868	\$8,458	6.70
San Diego-Lindbergh	29,996	0.46	\$58,013	\$0.891	\$8,458	6.86
Fullerton	30,339	0.46	\$58,700	\$0.889	\$8,458	6.94
Riverside	31,196	0.47	\$61,242	\$0.926	\$8,458	7.24
Sacramento	30,864	0.47	\$61,459	\$0.932	\$8,458	7.27
Fresno	31,935	0.49	\$63,559	\$0.963	\$8,458	7.51
Palmdale	31,286	0.47	\$61,882	\$0.932	\$8,458	7.32
Palm Springs	35,156	0.53	\$69,995	\$1.055	\$8,458	8.28

Maximum	65,726	0.74	\$ 129,036	\$ 1.59	\$ 10,149	12.71
Minimum	6,458	0.24	\$ 12,317	\$ 0.47	\$ 5,075	2.43

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Mechanical Subcooling

2. Liquid subcooling shall be provided for all low temperature parallel compressor systems with a design saturated suction temperature of -10°F or lower, with the subcooled liquid temperature maintained continuously at 50°F or less, using compressor economizer port(s) or a separate parallel medium or high temperature suction group operating at a saturated suction temperature of 18°F or higher.

EXCEPTION 1 to Section 127 (b) 2: Single compressor systems.

EXCEPTION 2 to Section 127 (b) 2: Low temperature cascade systems that condense into another refrigeration system rather than condensing to ambient temperature.

EXCEPTION 3 to Section 127 (b) 2: Existing compressors that are reused for an expansion or remodel,

Supermarket Refrigeration

Mechanical Subcooling

	Energy Savings (kWh)	Energy Savings/ SF (kWh)	TDV Cost Savings (\$)	TDV Cost Savings /SF (\$)	Measure Cost plus Maintenance Cost (\$)	Benefit/ Cost Ratio
SXX Average	9,012	0.57	\$18,543	\$1.17	\$4,475	4.14
MXX Average	25,483	0.43	\$53,461	\$0.90	\$7,973	6.71
LXX Average	65,849	0.41	\$137,909	\$0.85	\$14,221	9.70
XAX Average	26,748	0.37	\$64,115	\$0.87	\$8,694	7.37
XEX Average	26,739	0.37	\$51,989	\$0.71	\$9,673	5.37
XFX Average	43,502	0.62	\$84,818	\$1.20	\$8,694	9.76

All Average						
Arcata	28,837	0.41	\$54,668	\$0.772	\$8,890	6.15
Oakland	29,735	0.42	\$58,467	\$0.815	\$8,890	6.58
Santa Maria	29,532	0.42	\$57,315	\$0.800	\$8,890	6.45
San Diego-Lindbergh	31,193	0.44	\$62,173	\$0.866	\$8,890	6.99
Fullerton	32,359	0.46	\$66,352	\$0.946	\$8,890	7.46
Riverside	34,136	0.48	\$74,327	\$1.025	\$8,890	8.36
Sacramento	33,135	0.46	\$72,075	\$0.996	\$8,890	8.11
Fresno	35,542	0.49	\$77,962	\$1.076	\$8,890	8.77
Palmdale	34,923	0.48	\$75,368	\$1.036	\$8,890	8.48
Palm Springs	45,087	0.62	\$101,004	\$1.397	\$8,890	11.36

Maximum	114,292	0.87	\$259,844	\$2.341	\$15,793	20.85
Minimum	4,006	0.14	\$7,645	\$0.255	\$4,220	1.81

Supermarket Refrigeration

Liquid-Suction Heat Exchangers

(c) Liquid Suction Heat Exchangers.

1. All direct-expansion walk-in and display case circuits served by compressor suction groups with design saturated suction temperatures of 25°F SST or less shall be equipped with one or more liquid suction heat exchangers, sized to meet the temperature requirements in Table 127-B.

TABLE 127-B – LIQUID-SUCTION HEAT EXCHANGER SIZING REQUIREMENTS

Suction Group Design SST	Required Liquid Subcooling
SST < -5°F	15°F
-5°F ≤ SST ≤ 25°F	5°F

EXCEPTION 1 to Section 127 (c) 1: Systems utilizing CO₂ refrigerant.

EXCEPTION 2 to Section 127 (c) 1: Walk-ins with a saturated evaporating temperature of 28°F.

EXCEPTION 3 to Section 127 (c) 1: Walk-ins with an area of 150 square feet or smaller.

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Liquid Suction Heat Exchangers

	Energy Savings (kWh)	Energy Savings/ SF (kWh)	TDV Cost Savings (\$)	TDV Cost Savings /SF (\$)	Measure Cost (\$)	Benefit/ Cost Ratio
SXX Average	251	0.02	\$ 439	\$ 0.03	\$ 282	1.56
MOX Average	1,686	0.03	\$ 3,618	\$ 0.06	\$ 1,801	2.01
LXX Average	8,352	0.05	\$ 18,254	\$ 0.11	\$ 3,401	5.37
XAX Average	3,100	0.03	\$ 7,073	\$ 0.06	\$ 1,828	3.87
XEX Average	3,137	0.03	\$ 6,550	\$ 0.06	\$ 1,828	3.58
XFX Average	3,905	0.04	\$ 8,245	\$ 0.08	\$ 1,828	4.51

All Average						
Arcata	2,480	0.02	\$ 5,067	\$ 0.05	\$ 1,828	2.77
Oakland	2,888	0.03	\$ 6,102	\$ 0.05	\$ 1,828	3.34
Santa Maria	2,823	0.03	\$ 5,887	\$ 0.05	\$ 1,828	3.22
San Diego-Lindbergh	3,445	0.03	\$ 7,262	\$ 0.06	\$ 1,828	3.97
Fullerton	3,602	0.03	\$ 7,660	\$ 0.07	\$ 1,828	4.19
Riverside	3,651	0.03	\$ 8,044	\$ 0.07	\$ 1,828	4.40
Sacramento	3,366	0.03	\$ 7,460	\$ 0.07	\$ 1,828	4.08
Fresno	3,670	0.03	\$ 8,157	\$ 0.07	\$ 1,828	4.46
Palmdale	3,422	0.03	\$ 7,589	\$ 0.07	\$ 1,828	4.15
Palm Springs	4,948	0.05	\$ 11,144	\$ 0.10	\$ 1,828	6.10

Maximum	13,990	0.09	\$ 32,137	\$ 0.20	\$ 3,401	9.45
Minimum	-193	-0.01	\$ (756)	\$ (0.05)	\$ 282	-2.68

BC
Ratio
Less
than 1



Medium-Temperature Walk-Ins

Supermarket Refrigeration

Liquid Suction Heat Exchangers

	Energy Savings (kWh)	Energy Savings/SF (kWh)	TDV Cost Savings (\$)	TDV Cost Savings /SF (\$)	Measure Cost (\$)	Benefit/Cost Ratio
SXX Average	607	0.04	\$1,252	\$0.08	\$452	2.77
MXX Average	4,491	0.08	\$8,943	\$0.15	\$718	12.46
LXX Average	46,961	0.29	\$93,788	\$0.58	\$5,263	17.82
XAX Average	16,119	0.12	\$33,067	\$0.25	\$2,144	15.42
XEX Average	16,878	0.13	\$33,190	\$0.26	\$2,144	15.48
XFX Average	18,825	0.15	\$36,990	\$0.29	\$2,144	17.25

All Average						
Arcata	15,192	0.12	\$29,343	\$0.227	\$2,144	13.69
Oakland	16,157	0.13	\$31,666	\$0.246	\$2,144	14.77
Santa Maria	15,957	0.12	\$31,218	\$0.242	\$2,144	14.56
San Diego	17,518	0.14	\$34,723	\$0.272	\$2,144	16.19
Fullerton	17,726	0.14	\$35,071	\$0.274	\$2,144	16.36
Riverside	17,826	0.14	\$35,934	\$0.280	\$2,144	16.76
Sacramento	17,148	0.13	\$34,877	\$0.272	\$2,144	16.27
Fresno	17,970	0.14	\$36,521	\$0.284	\$2,144	17.03
Palmdale	17,333	0.13	\$35,070	\$0.272	\$2,144	16.36
Palm Springs	20,703	0.16	\$42,187	\$0.325	\$2,144	19.67

Maximum	64,175	0.40	\$138,790	\$0.856	\$5,263	26.37
Minimum	446	0.03	\$863	\$0.054	\$452	1.91

Low-Temperature Walk-Ins

Supermarket Refrigeration

Liquid Suction Heat Exchangers

	Energy Savings (kWh)	Energy Savings/SF (kWh)	TDV Cost Savings (\$)	TDV Cost Savings /SF (\$)	Measure Cost (\$)	Benefit/Cost Ratio
SXX Average	3,536	0.22	\$7,507	\$0.47	\$1,577	4.76
MXX Average	15,663	0.26	\$33,934	\$0.57	\$6,710	5.06
LXX Average	2,329	0.01	\$5,052	\$0.03	\$840	6.02
XAX Average	5,962	0.14	\$13,710	\$0.32	\$3,042	4.51
XEX Average	6,761	0.16	\$13,843	\$0.32	\$3,042	4.55
XFX Average	8,597	0.20	\$18,113	\$0.42	\$3,042	5.95

All Average						
Arcata	5,680	0.13	\$11,327	\$0.267	\$3,042	3.72
Oakland	6,339	0.15	\$13,073	\$0.307	\$3,042	4.30
Santa Maria	6,155	0.14	\$12,527	\$0.294	\$3,042	4.12
San Diego-Lindbergh	7,766	0.18	\$16,232	\$0.378	\$3,042	5.34
Fullerton	7,607	0.17	\$16,138	\$0.370	\$3,042	5.30
Riverside	7,562	0.18	\$16,720	\$0.387	\$3,042	5.50
Sacramento	7,022	0.16	\$15,660	\$0.362	\$3,042	5.15
Fresno	7,559	0.17	\$16,911	\$0.387	\$3,042	5.56
Palmdale	6,600	0.15	\$14,719	\$0.338	\$3,042	4.84
Palm Springs	9,466	0.22	\$21,671	\$0.492	\$3,042	7.12

Maximum	24,007	0.40	\$52,944	\$0.889	\$6,710	11.88
Minimum	1,307	0.01	\$2,385	\$0.015	\$840	2.26

Medium-Temperature Display Cases

Supermarket Refrigeration

Liquid Suction Heat Exchangers

	Energy Savings (kWh)	Energy Savings/SF (kWh)	TDV Cost Savings (\$)	TDV Cost Savings /SF (\$)	Measure Cost (\$)	Benefit/ Cost Ratio
SXX Average	7,344	0.46	\$14,339	\$0.90	\$1,095	13.10
MXX Average	23,222	0.39	\$46,457	\$0.78	\$2,592	17.92
LXX Average	10,781	0.07	\$21,543	\$0.13	\$2,953	7.30
XAX Average	12,269	0.28	\$25,085	\$0.56	\$2,213	11.33
XEX Average	13,261	0.29	\$25,839	\$0.57	\$2,213	11.67
XFX Average	15,557	0.34	\$30,611	\$0.67	\$2,213	13.83

All Average						
Arcata	12,345	0.28	\$23,747	\$0.532	\$2,213	10.73
Oakland	13,066	0.29	\$25,528	\$0.569	\$2,213	11.53
Santa Maria	12,890	0.29	\$25,050	\$0.560	\$2,213	11.32
San Diego-Lindbergh	14,394	0.32	\$28,375	\$0.624	\$2,213	12.82
Fullerton	14,047	0.31	\$27,867	\$0.610	\$2,213	12.59
Riverside	14,045	0.31	\$28,418	\$0.625	\$2,213	12.84
Sacramento	13,482	0.30	\$27,503	\$0.606	\$2,213	12.43
Fresno	14,143	0.31	\$28,741	\$0.631	\$2,213	12.98
Palmdale	13,396	0.30	\$27,140	\$0.600	\$2,213	12.26
Palm Springs	16,018	0.35	\$32,093	\$0.701	\$2,213	14.50

Maximum	30,598	0.57	\$60,349	\$1.179	\$2,953	23.28
Minimum	5,896	0.05	\$11,018	\$0.096	\$1,095	5.26

Low-Temperature Display Cases

Supermarket Refrigeration

Liquid Suction Heat Exchangers

- MT Walk-in LSHX not cost-effective for small supermarket in any climate zone
 - LSHX cost is non-linear vs. capacity
 - Analysis performed to establish minimum SF:

Walk-In	Area (SF)	Savings (kWh/SF)	TDV Savings (\$TDV)	LSHX Cost (\$)	B/C Ratio
CTZ01 - Arcata					
Deli Cooler	64	28.6	\$66	\$149	0.44
Bakery Retarder	70	31.3	\$72	\$151	0.48
Meat Holding	91	40.7	\$93	\$155	0.60
Wine Cooler	121	54.1	\$124	\$160	0.78
Produce Cooler	400	179.0	\$411	\$199	2.07
Meat Cooler	540	241.6	\$554	\$224	2.47
Dairy Cooler	656	293.5	\$673	\$241	2.79
All WI	1942	869.0	\$1,994	\$1,801	1.11

- Conclusion: exception needed at 150 SF, for medium temperature boxes

Supermarket Refrigeration

Liquid Suction Heat Exchangers

- Issue raised concerning higher return gas temp and excessive discharge temperature for LT systems and some refrigerants
 - Measure costs include additional ¼" suction line insulation to minimize superheat after LSHX
- Compared superheat vs. subcooling for various refrigerants:

	Liquid Subcooling with Concurrent 15°F of Superheat (MT Systems)	Liquid Subcooling with Concurrent 35°F of Superheat (LT Systems)
R-404A/507	7°F	17°F
R-407A	9°F	19°F
R-410A	9°F	19°F

Supermarket Refrigeration

Display Case Lighting Control

(d) Display Cases.

1. Lighting in refrigeration display cases, and lights on glass doors installed on walk-in coolers and freezers shall be controlled by either A or B:
 - a. Automatic time switch controls to turn off lights during non-business hours. Use of timed overrides to turn the lights for stocking shall not exceed one hour for any case line-up or walk-in and if manually initiated shall time-out automatically.
 - b. Motion sensor controls on each case that reduce display case lighting power by at least 50% within 30 minutes after the area near the case is vacated.

EXCEPTION 1 to Section 127 (d) 1: Stores which are normally open for business 140 hours or more per week.

Supermarket Refrigeration

Display Case Lighting Control

	Energy Savings (kWh)	Energy Savings/ SF (kWh)	TDV Cost Savings (\$)	TDV Cost Savings /SF (\$)	Measure Cost plus Maintenance Cost (\$)	Benefit/ Cost Ratio
SXX Average	49,627	3.13	\$69,134	\$4.36	\$5,588	12.37
MXA Average	149,814	2.52	\$219,138	\$3.68	\$11,321	19.36
LXX Average	173,263	1.07	\$265,992	\$1.64	\$12,659	21.01
XAX Average	122,362	2.21	\$181,772	\$3.18	\$9,856	18.44
XEX Average	121,355	2.19	\$180,092	\$3.15	\$9,856	18.27
XFX Average	127,547	2.29	\$190,068	\$3.31	\$9,856	19.28

All Average						
Arcata	121,760	2.20	\$182,231	\$3.189	\$9,856	18.49
Oakland	122,526	2.21	\$181,454	\$3.173	\$9,856	18.41
Santa Maria	122,016	2.20	\$182,338	\$3.183	\$9,856	18.50
San Diego-Lindbergh	125,402	2.26	\$189,148	\$3.292	\$9,856	19.19
Fullerton	124,593	2.24	\$184,423	\$3.209	\$9,856	18.71
Riverside	124,596	2.24	\$182,220	\$3.174	\$9,856	18.49
Sacramento	123,529	2.22	\$184,090	\$3.210	\$9,856	18.68
Fresno	125,199	2.26	\$187,412	\$3.293	\$9,856	19.01
Palmdale	124,213	2.24	\$182,442	\$3.195	\$9,856	18.51
Palm Springs	128,513	2.31	\$191,788	\$3.356	\$9,856	19.46

Maximum	185,047	3.29	\$285,101	\$4.623	\$12,659	22.52
Minimum	47,749	1.02	\$66,267	\$1.552	\$5,588	11.86

Supermarket Refrigeration

Prohibit Open Upright Frozen Food Cases

2. Upright low temperature display cases that are designed for a supply air temperature of 5°F or lower shall utilize reach-in glass doors.

	Energy Savings (kWh)	Energy Savings/SF (kWh)	TDV Cost Savings (\$)	TDV Cost Savings /SF (\$)
MAC	7,767	0.13	19,481	\$0.33
MAD	9,526	0.16	22,311	\$0.37
MEC	9,990	0.17	22,116	\$0.37
MFC	11,094	0.19	25,017	\$0.42
MFD	11,218	0.19	25,017	\$0.42
ALL Average	9,919	0.17	22,789	\$0.38

- No cost associated with this measure so no benefit/cost analysis was performed

Supermarket Refrigeration

Heat Recovery for Space Heating

(e) Refrigeration Heat Recovery

1. Refrigeration and HVAC systems shall utilize 25% or more of the design Heat of Rejection of all refrigeration systems for space heating.
2. The increase in HFC refrigerant charge for associated with refrigeration heat recovery shall be no greater than 20% of the total refrigerant charge without heat recovery, or 0.50 lbs per 1,000 BTU/Hr of heating capacity, whichever is less.

Supermarket Refrigeration

Heat Recovery for Space Heating

	Energy Savings (kWh)	Energy Savings/SF (kWh)	Natural Gas Savings (Therms)	Natural Gas Savings /SF (Therms)	TDV Cost Savings (\$)	TDV Cost Savings /SF (\$)	Measure Cost plus Maintenance Cost (\$)	Benefit/ Cost Ratio
SXX Average	-15,885	-1.00	7,573	0.48	\$126,510	\$7.98	\$21,396	5.91
MXX Average	-37,045	-0.62	26,572	0.45	\$478,112	\$8.03	\$69,949	6.84
LXX Average	-94,772	-0.58	35,118	0.22	\$540,915	\$3.34	\$88,378	6.12
XAX Average	-70,370	-1.10	23,006	0.38	\$336,229	\$5.68	\$60,813	5.53
XEX Average	-53,986	-0.80	23,061	0.38	\$371,734	\$6.31	\$57,021	6.52
XFX Average	-25,722	-0.34	23,183	0.38	\$432,518	\$7.29	\$60,446	7.16

All Average								
Arcata	-53,400	-0.78	43,977	0.69	\$771,752	\$12.35	\$59,908	12.88
Oakland	-48,367	-0.70	31,436	0.50	\$545,607	\$8.88	\$59,908	9.11
Santa Maria	-49,166	-0.71	33,001	0.53	\$568,282	\$9.20	\$59,908	9.49
San Diego-Lindbergh	-41,375	-0.59	17,696	0.31	\$284,389	\$5.27	\$59,908	4.75
Fullerton	-46,948	-0.73	16,646	0.32	\$256,694	\$5.28	\$59,908	4.28
Riverside	-49,868	-0.75	16,704	0.28	\$257,436	\$4.39	\$59,908	4.30
Sacramento	-53,112	-0.80	23,756	0.39	\$399,091	\$6.60	\$59,908	6.66
Fresno	-50,693	-0.77	19,960	0.33	\$331,549	\$5.52	\$59,908	5.53
Palmdale	-56,213	-0.86	21,598	0.35	\$358,692	\$5.91	\$59,908	5.99
Palm Springs	-43,199	-0.67	6,096	0.11	\$44,962	\$1.07	\$59,908	0.75

Maximum	84,118	1.41	72,907	0.86	\$1,329,152	\$18.95	\$95,545	15.90
Minimum	-150,070	-1.93	2,250	0.05	-\$8,260	\$(0.05)	\$20,926	-0.10

BC
Ratio
Less
than 1



Supermarket Refrigeration

Heat Recovery for Space Heating

	Energy Savings (kWh)	Energy Savings/SF (kWh)	Natural Gas Savings (Therms)	Natural Gas Savings /SF (Therms)	TDV Electric Cost Savings (\$)	TDV Gas Cost Savings (\$)	TDV Total Cost Savings (\$)	TDV Total Cost Savings /SF (\$)	Measure Cost plus Maintenance Cost (\$)	Benefit/ Cost Ratio
SAC	-14,987	-0.95	2,250	0.14	\$ (32,539)	\$ 51,689	\$ 19,150	\$ 1.21	\$ 20,926	0.92
SAD	-15,793	-1.00	2,250	0.14	\$ (33,933)	\$ 51,689	\$ 17,756	\$ 1.12	\$ 23,202	0.77
SEC	-15,409	-0.97	2,250	0.14	\$ (33,220)	\$ 51,677	\$ 18,457	\$ 1.16	\$ 20,926	0.88
SFC	-10,655	-0.67	2,251	0.14	\$ (24,154)	\$ 51,726	\$ 27,572	\$ 1.74	\$ 20,926	1.32
SFD	-10,901	-0.69	2,251	0.14	\$ (24,265)	\$ 51,726	\$ 27,461	\$ 1.73	\$ 21,000	1.31
MAC	-48,067	-0.81	8,532	0.14	\$ (105,335)	\$ 194,802	\$ 89,467	\$ 1.50	\$ 66,536	1.34
MAD	-51,536	-0.87	8,532	0.14	\$ (110,844)	\$ 194,802	\$ 83,958	\$ 1.41	\$ 75,068	1.12
MEC	-47,445	-0.80	8,529	0.14	\$ (102,926)	\$ 194,728	\$ 91,802	\$ 1.54	\$ 66,536	1.38
MFC	-25,995	-0.44	8,538	0.14	\$ (61,800)	\$ 194,949	\$ 133,148	\$ 2.24	\$ 66,536	2.00
MFD	-26,917	-0.45	8,538	0.14	\$ (61,455)	\$ 194,949	\$ 133,494	\$ 2.24	\$ 75,068	1.78
LAC	-83,699	-0.52	7,502	0.05	\$ (181,108)	\$ 172,848	\$ (8,260)	\$ (0.05)	\$ 83,600	-0.10
LAD	-81,478	-0.50	7,499	0.05	\$ (176,625)	\$ 172,775	\$ (3,850)	\$ (0.02)	\$ 95,545	-0.04
LEC	-81,558	-0.50	7,502	0.05	\$ (177,216)	\$ 172,848	\$ (4,368)	\$ (0.03)	\$ 83,600	-0.05
LFC	-67,603	-0.42	7,507	0.05	\$ (151,067)	\$ 172,983	\$ 21,916	\$ 0.14	\$ 83,600	0.26
LFD	-65,948	-0.41	7,506	0.05	\$ (146,216)	\$ 172,946	\$ 26,731	\$ 0.16	\$ 95,545	0.28
SXX Average	-13,549	-0.85	2,250	0.14	\$ (29,622)	\$ 51,702	\$ 22,079	\$ 1.39	\$ 21,396	1.03
MXX Average	-39,992	-0.67	8,534	0.14	\$ (88,472)	\$ 194,846	\$ 106,374	\$ 1.79	\$ 69,949	1.52
LXX Average	-76,057	-0.47	7,503	0.05	\$ (166,447)	\$ 172,880	\$ 6,434	\$ 0.04	\$ 88,378	0.07
XAX Average	-49,260	-0.77	6,094	0.11	\$ (106,731)	\$ 139,768	\$ 33,037	\$ 0.86	\$ 60,813	0.54
XEX Average	-48,137	-0.76	6,094	0.11	\$ (104,454)	\$ 139,751	\$ 35,297	\$ 0.89	\$ 57,021	0.62
XFX Average	-34,670	-0.51	6,099	0.11	\$ (78,159)	\$ 139,880	\$ 61,720	\$ 1.37	\$ 60,446	1.02
ALL Average	-43,199	-0.67	6,096	0.11	\$ (94,847)	\$ 139,809	\$ 44,962	\$ 1.07	\$ 59,908	0.75

Results: CTZ15 – Palm Springs

Supermarket Refrigeration

Heat Recovery – Charge Impacts

	Measure Cost (\$)	Refrigerant Cost Savings Range (\$)		TDV Energy Cost Savings (\$)	Carbon Cost Savings Range (\$)		Net Savings Range (\$)	
		High	Low		High	Low	High	Low
SXX Average	\$21,396	-\$2,414	-\$3,956	\$126,510	\$1,233	-\$9,435	\$103,934	\$91,722
MXX Average	\$69,949	-\$12,144	-\$19,905	\$478,112	-\$17,192	-\$70,876	\$378,828	\$317,383
LXX Average	\$88,378	-\$14,315	-\$23,465	\$540,915	-\$24,105	-\$89,836	\$414,117	\$339,236
XAX Average	\$60,813	-\$9,922	-\$16,124	\$336,229	-\$20,096	-\$63,813	\$245,397	\$195,479
XEX Average	\$57,021	-\$16,357	-\$27,262	\$371,734	-\$61,883	-\$138,755	\$236,473	\$148,697
XFX Average	\$60,446	-\$5,959	-\$9,683	\$432,518	\$17,653	-\$8,599	\$383,766	\$353,790

All Average								
Arcata	\$59,908	-\$9,624	-\$15,775	\$771,752	\$44,374	\$1,013	\$746,594	\$697,082
Oakland	\$59,908	-\$9,624	-\$15,775	\$545,607	\$10,245	-\$33,117	\$486,320	\$436,807
Santa Maria	\$59,908	-\$9,624	-\$15,775	\$568,282	\$14,468	-\$28,893	\$513,219	\$463,706
San Diego-Lindbergh	\$59,908	-\$9,624	-\$15,775	\$284,389	-\$26,838	-\$70,200	\$188,019	\$138,507
Fullerton	\$59,908	-\$9,624	-\$15,775	\$256,694	-\$30,944	-\$74,305	\$156,219	\$106,706
Riverside	\$59,908	-\$9,624	-\$15,775	\$257,436	-\$31,391	-\$74,753	\$156,513	\$107,001
Sacramento	\$59,908	-\$9,624	-\$15,775	\$399,091	-\$12,284	-\$55,646	\$317,275	\$267,762
Fresno	\$59,908	-\$9,624	-\$15,775	\$331,549	-\$22,429	-\$65,790	\$239,589	\$190,076
Palmdale	\$59,908	-\$9,624	-\$15,775	\$358,692	-\$18,987	-\$62,349	\$270,173	\$220,661
Palm Springs	\$59,908	-\$9,624	-\$15,775	\$44,962	-\$59,755	-\$103,117	-\$84,324	-\$133,837

Maximum Net Savings	\$1,371,700	\$1,353,583
Minimum Net Savings	-\$283,217	-\$416,070

Palm
Springs



- Economics with refrigerant charge analysis

Supermarket Refrigeration

Heat Recovery for Space Heating

- Analysis based on full heat recovery; code requirement is at least 25% of design THR:
 - Multitudes of combinations between refrigeration systems types, HVAC system types and configurations, store sizes and new construction project types.
- Exception required for climate zone or design temperature. Input?
- Requirement to limit refrigerant charge increase. Input?

Supermarket Refrigeration

Evaporator Coil Fan Variable Speed

(a) Walk-In Evaporators and Cooling Coils

1. Fan-powered walk-in evaporators or secondary cooling coils shall utilize variable speed fan control as the primary means of space temperature control, with a minimum speed setpoint of 80% or less and with other flow controls or pressure controls employed only after the minimum speed setpoint has been reached.
 2. Use of fan speed override controls to periodically increase fan speed shall not exceed 25% of the non-defrost operating hours, or a duration of eight hours if manually enabled.
- Speed control must be the primary means of temperature control—reduce to minimum speed before floating suction, liquid solenoid, suction regulator.
 - Allows for timed overrides or full speed duty cycle

Supermarket Refrigeration

Evaporator Coil Fan Variable Speed

	Energy Savings (kWh)	Energy Savings/ SF (kWh)	TDV Cost Savings (\$)	TDV Cost Savings /SF (\$)	Measure Cost (\$)	Benefit/ Cost Ratio
SXX Average	3,971	0.25	\$9,499	\$0.60	\$5,377	1.77
MXX Average	26,677	0.45	\$63,330	\$1.06	\$15,529	4.08
LXX Average	143,019	0.88	\$343,523	\$2.12	\$23,667	14.51
XAX Average	57,077	0.52	\$137,278	\$1.24	\$14,858	9.24
XEX Average	56,224	0.51	\$134,362	\$1.22	\$14,858	9.04
XFX Average	59,533	0.54	\$142,502	\$1.30	\$14,858	9.59

All Average						
Arcata	56,615	0.52	\$134,578	\$1.229	\$14,858	9.06
Oakland	57,182	0.52	\$136,760	\$1.245	\$14,858	9.20
Santa Maria	57,072	0.52	\$136,590	\$1.245	\$14,858	9.19
San Diego-Lindbergh	58,138	0.53	\$140,719	\$1.283	\$14,858	9.47
Fullerton	58,095	0.53	\$138,707	\$1.260	\$14,858	9.34
Riverside	58,172	0.53	\$139,038	\$1.262	\$14,858	9.36
Sacramento	57,886	0.53	\$139,601	\$1.266	\$14,858	9.40
Fresno	58,275	0.53	\$140,384	\$1.271	\$14,858	9.45
Palmdale	57,930	0.53	\$138,453	\$1.253	\$14,858	9.32
Palm Springs	59,525	0.54	\$143,012	\$1.292	\$14,858	9.63

Maximum	153,159	0.94	\$369,171	\$2.277	\$23,667	15.60
Minimum	3,763	0.24	\$8,917	\$0.563	\$5,377	1.66

Supermarket Refrigeration

Evaporator Coil Fan Variable Speed

- Rationale for classifying as Reach measure:
 - Lack of experience with evaporator fan speed control in this supermarket walk-ins
 - Vendors in the process of developing technology
- Need industry input:
 - Will technology and control logic be in place by code effective date?
 - What other exceptions are needed?
 - Should only medium profile evaporators be covered (very high savings)?

Supermarket Refrigeration

CO₂ Secondary (indirect) or Cascade Cooling

(b) CO₂ Indirect or Cascade Cooling Systems

Tentative pending additional stakeholder input and clarification on TDV values:

1. Cooling for all refrigerated display cases and walk-in coolers and freezers shall be provided using carbon dioxide (CO₂), connected to compressors as a direct expansion refrigerant, or as a phase-change indirect cooling fluid.

EXCEPTION 1 to Section 127 (b) 1: Stores with less than 20,000 square feet of sales area.

EXCEPTION 2 to Section 127 (b) 1: Existing compressor systems that are reused for an expansion or remodel,

Supermarket Refrigeration

CO₂ Secondary (indirect) or Cascade Cooling

	Energy Savings (kWh)	Energy Savings/ SF (kWh/SF)	TDV Cost Savings (\$)	TDV Cost Savings /SF (\$)	Measure Cost (\$)	Benefit/ Cost Ratio
SAC (CO ₂ Cascade)	-49,392	-3.12	-\$100,722	-6.36	\$50,000	-2.01
MAC (CO ₂ Indirect)	-168,063	-2.82	-\$322,477	-5.41	\$150,000	-2.15
Average	-108,727	-2.97	-\$211,600	-5.88	\$100,000	-2.12

All Average						
Arcata	-148,868	-4.08	-\$275,280	-7.61	\$100,000	-2.75
Oakland	-151,793	-4.18	-\$283,312	-7.84	\$100,000	-2.83
Santa Maria	-151,802	-4.17	-\$283,815	-7.86	\$100,000	-2.84
San Diego-Lindbergh	-155,629	-4.31	-\$293,040	-8.16	\$100,000	-2.93
Fullerton	-74,297	-2.01	-\$149,492	-4.24	\$100,000	-1.49
Riverside	-77,655	-2.10	-\$159,206	-4.46	\$100,000	-1.59
Sacramento	-75,610	-2.03	-\$157,360	-4.38	\$100,000	-1.57
Fresno	-79,725	-2.15	-\$164,996	-4.59	\$100,000	-1.65
Palmdale	-79,736	-2.14	-\$163,656	-4.52	\$100,000	-1.64
Palm Springs	-92,163	-2.53	-\$185,839	-5.20	\$100,000	-1.86

Minimum	-32,847	-1.94	-\$74,909	-3.76	150,000	-1.49
Maximum	-238,154	-4.61	-\$446,274	-8.82	50,000	-2.98

Supermarket Refrigeration

CO₂ Secondary – Charge Impacts

	Measure Cost (\$)	Refrigerant Cost Savings Range (\$)		TDV Cost Savings (\$)	Carbon Cost Savings Range (\$)		Net Savings Range (\$)		Benefit/Cost Ratio Range	
Small Supermarket/Cascade System										
Arcata	\$50,000	\$13,044	\$19,986	(\$129,063)	\$75,986	\$124,000	(\$90,033)	(\$35,078)	(1.80)	(0.70)
Oakland	\$50,000	\$13,044	\$19,986	(\$133,077)	\$75,558	\$123,572	(\$94,475)	(\$39,519)	(1.89)	(0.79)
Santa Maria	\$50,000	\$13,044	\$19,986	(\$133,468)	\$75,602	\$123,616	(\$94,822)	(\$39,867)	(1.90)	(0.80)
San Diego	\$50,000	\$13,044	\$19,986	(\$139,805)	\$74,977	\$122,990	(\$101,784)	(\$46,829)	(2.04)	(0.94)
Fullerton	\$50,000	\$13,044	\$19,986	(\$74,909)	\$83,373	\$131,387	(\$28,491)	\$26,464	(0.57)	0.53
Riverside	\$50,000	\$13,044	\$19,986	(\$77,196)	\$83,013	\$131,027	(\$31,139)	\$23,817	(0.62)	0.48
Sacramento	\$50,000	\$13,044	\$19,986	(\$74,909)	\$83,373	\$131,387	(\$28,491)	\$26,464	(0.57)	0.53
Fresno	\$50,000	\$13,044	\$19,986	(\$78,611)	\$82,886	\$130,900	(\$32,680)	\$22,275	(0.65)	0.45
Palmdale	\$50,000	\$13,044	\$19,986	(\$76,493)	\$83,042	\$131,056	(\$30,406)	\$24,549	(0.61)	0.49
Palm Springs	\$50,000	\$13,044	\$19,986	(\$89,691)	\$81,411	\$129,425	(\$45,236)	\$9,719	(0.90)	0.19
Large supermarket										
Arcata	\$150,000	\$65,557	\$100,357	(\$421,498)	\$405,586	\$646,297	(\$100,354)	\$175,156	(0.67)	1.17
Oakland	\$150,000	\$65,557	\$100,357	(\$433,548)	\$404,794	\$645,504	(\$113,197)	\$162,313	(0.75)	1.08
Santa Maria	\$150,000	\$65,557	\$100,357	(\$434,162)	\$404,746	\$645,456	(\$113,859)	\$161,652	(0.76)	1.08
San Diego	\$150,000	\$65,557	\$100,357	(\$446,274)	\$403,775	\$644,485	(\$126,942)	\$148,568	(0.85)	0.99
Fullerton	\$150,000	\$65,557	\$100,357	(\$224,076)	\$429,306	\$670,016	\$120,787	\$396,298	0.81	2.64
Riverside	\$150,000	\$65,557	\$100,357	(\$241,217)	\$428,265	\$668,976	\$102,605	\$378,116	0.68	2.52
Sacramento	\$150,000	\$65,557	\$100,357	(\$239,811)	\$428,758	\$669,468	\$104,504	\$380,015	0.70	2.53
Fresno	\$150,000	\$65,557	\$100,357	(\$251,380)	\$427,528	\$668,239	\$91,705	\$367,216	0.61	2.45
Palmdale	\$150,000	\$65,557	\$100,357	(\$250,820)	\$427,368	\$668,078	\$92,105	\$367,616	0.61	2.45
Palm Springs	\$150,000	\$65,557	\$100,357	(\$281,986)	\$423,815	\$664,526	\$57,386	\$332,897	0.38	2.22

Supermarket Refrigeration

CO₂ Secondary (indirect) or Cascade Cooling

- Cost-benefit ratio is not consistently attractive, particularly for cascade design
- Uncertainties:
 - Incremental cost information is limited.
 - Certain simulation assumptions (e.g. loop heat gains) may be overly conservative.
- Additional input needed from stakeholders
- Single-phase glycol would not meet the requirement, based on the much larger increase in energy usage.

Supermarket Refrigeration

Acceptance Testing

- Acceptance testing procedures will be developed for control-related measures.

Supermarket Refrigeration



QUESTIONS & COMMENTS